Solar Thermal Propulsion Absorber/Thruster

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In-house studies at MSFC show reduced costs for orbit transfer using solar thermal propulsion (STP) systems. STP uses concentrated sunlight inside an absorber cavity to heat hydrogen (to 2,700 K) and expel it from a conical nozzle. STP systems are low thrust (4.4 to 44 N) and require about a month to transfer payloads from low-Earth orbit to geosynchronous-Earth orbit. Cost savings are primarily from reduced weight and high specific impulses (800 to 900 sec). A ground demonstration STP absorber/thruster has been designed and fabricated with two main objectives:

- Develop a STP fabrication procedure; and
- Verify expected STP performance with simulated ground tests.

The design (fig. 3) of MSFC's first STP absorber/thruster is cylindrical for simplicity and operates under the "direct gain" principle (focused sunlight provides immediate thrust). The inner cavity is highly reflective close to the front opening (833-K surface temperature) and more absorbing deep inside (2,700 K surface temperature) to control light distribution of high-energy solar wavelengths. Heat transfer of solar energy energizes the propellant, hydrogen.

Tungsten ($4/N) is the refractory metal with the highest melting point and was selected for the first thruster. Rhenium ($133/N) has the next highest melting point, but is very costly. Tungsten is brittle and very difficult to machine at room temperatures. A procedure has been developed that fabricates inner and outer tungsten shells which, when joined, creates an absorber cavity with helical flow channels and a nozzle. The procedure involves vacuum plasma spraying tungsten over a graphite mandrel with an outer surface designed to meet requirements of the inner surface of a tungsten shell. The graphite is removed with a drill bit and plastic bead blaster. Shell length is cut using a brass wire electric discharge machine (EDM). A hone device using polyurethane pads, diamond powder, and a glycerin slurry was used to polish the tungsten surface inside the absorber to 75 percent reflectivity. Figure 4 shows an outer shell made of tungsten. The tungsten shells are brazed to a nickel face plate, which has hydrogen inlet lines.

Insulation is made of a rigidized graphite felt to lower temperatures on the thruster's outer surface to 444 K. Graphite diffuses into tungsten at high temperatures. A protective coating of tantalum carbide (TaC) or niobium carbide (NbC) is required at each material interface to minimize a buildup of tungsten carbide.

The next STP absorber/thruster will be made of a tungsten/rhenium alloy ($44/N) which has better ductility. The fabrication procedures developed from the first thruster greatly reduces the time and cost associated with expensive material.

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Biographical Sketch: Harold P. Gerrish Jr. is an aerospace engineer for MSFC's Propulsion Systems branch. He is principal investigator for the STP project funded by CDDF and leads a small team charged with thruster design/fabrication and activation of special test equipment for ground demonstrations. His 10 years in propulsion cover solar thermal propulsion, nuclear thermal propulsion, and hypergolic combustion engines. He received a B.S. in aerospace engineering from Auburn University, and an M.S. in aeronautics and astrnonautics from Purdue University.

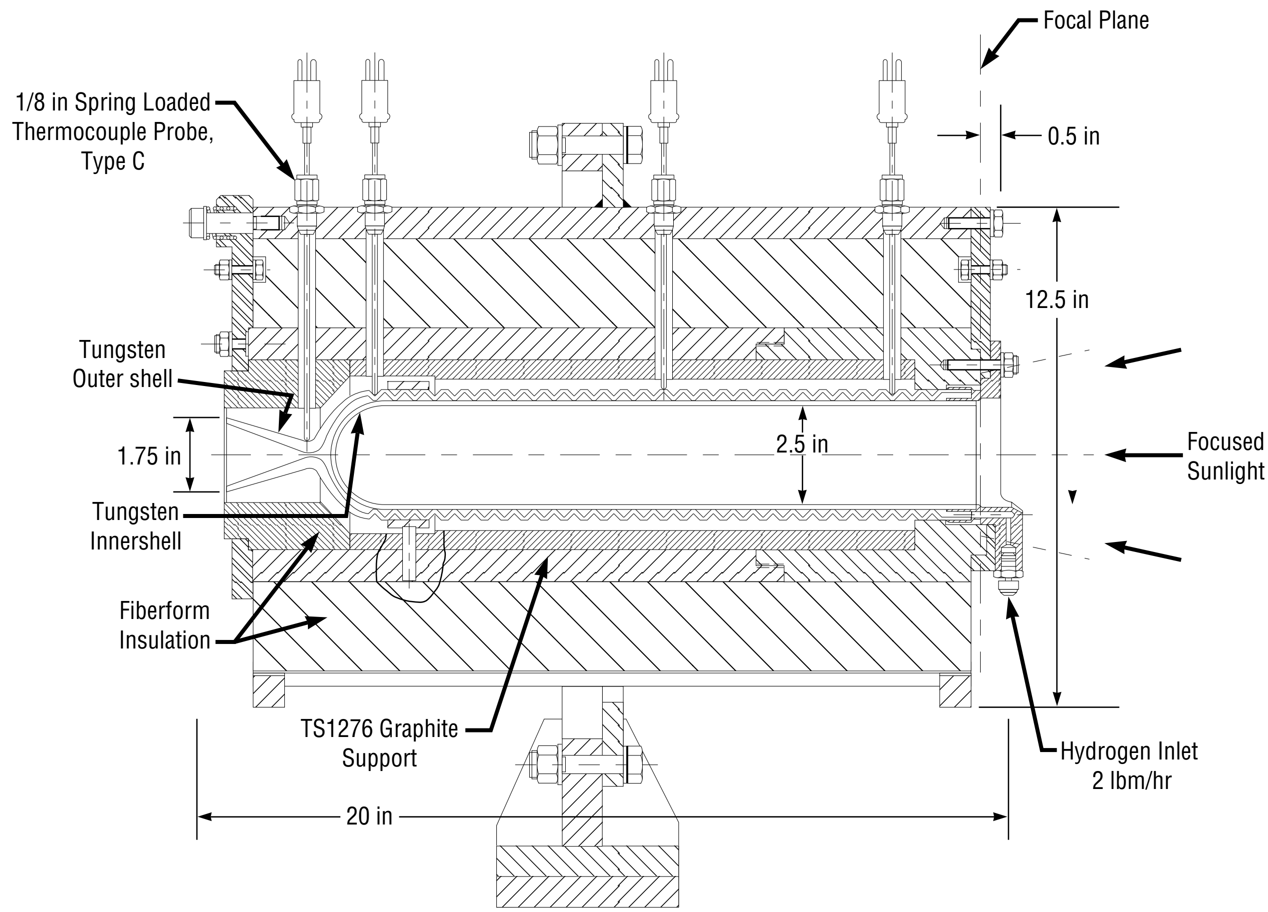

Figure 3.—Phase I solar thermal propulsion absorber/thruster design.

Figure 4.—Tungsten outer shell with helical flow channels and nozzle.